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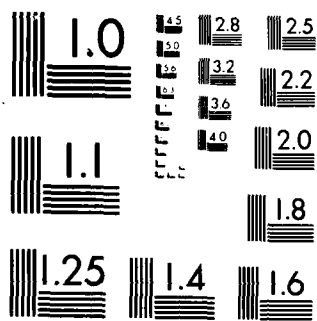
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Final Report

on

Wave Dispersion Mechanisms in Large Space Structures
(Contract F49620-83-C-0018)

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October 1985

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| 19. ABSTRACT (Continue on reverse if necessary and identify by block number) *This report describes an investigation into wave dispersion phenomena in large lattice space structures. Particular results were: 1) That local member dynamic characteristics significantly influence global dynamic response; 2) That it is possible to increase dispersion of wave energy in lattice-truss structures by adopting a nonuniform lattice construction; and 3) That local member dynamics characteristics require detailed modeling techniques which are capable of capturing member bending behavior in order to assess, realistically, the influence of local phenomena on global dynamic response. | | | | | |
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1. Objectives

The objectives of the present research (contract No. F49620-83-C-0018) have been:

- a) To determine the influences of the local dynamics of individual members on the global dynamic response of large lattice-truss structures.
- b) To examine improvements to energy dispersion mechanisms within such structures by tailoring the interactions between local truss member dynamic characteristics and global dynamic responses.

2. Progress

The results of the present research have been described in detail in earlier reports entitled: "Local-Global Interactions in the Transient Response of Lattice-Truss Plates" (LMSC-D878939), "Transient Energy Distributions in a Large Lattice-Truss Space Platform - A Computer-Generated Animation" (with accompanying 16mm. film), and "A Momentum and Energy Conserving Algorithm for Contact-Impact Problems." These results were derived through the application of analytical developments to numerical simulations of lattice-truss dynamics. Significant progress has been made in the following areas:

- a) Development of effective techniques for dynamic modeling of large, multiply-connected truss structures.
- b) Use of animation for review and qualitative assessment of key simulation results.
- c) Demonstration of the significant influences of local member dynamic characteristics on global structural dynamic response.
- d) Validation of techniques for modification of vibration energy dispersion patterns by tailoring individual member dynamic characteristics.

These areas are described in detail in the following paragraphs.

2.1 Modeling Techniques

Continuum, equivalent, or other reduced-order modeling techniques eliminate the detail required for investigation of local dynamics by smearing individual member properties over a larger region of the structure. As such, reduced-order modeling techniques are primarily useful for investigations of *global* dynamics, i.e. motions occurring on a geometric scale comparable to that of the whole structure. Hence, in order to study local dynamics of individual truss members, it is necessary to make use of discrete modeling techniques at the local member level.



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The use of discrete modeling techniques greatly increases the size and scope of structural dynamic models. In addition, the multiply-connected nature of lattice-truss plates produces high bandwidths in the algebraic equation systems which describe the structural dynamics. Therefore, conventional strategies for dealing with such large models such as modal decomposition or direct time-integration methods which require factorization of assembled system matrices are of limited utility as the demands placed on computational resources severely limit the practical size of structural models. To overcome this difficulty, an element-by-element explicit integration scheme was developed. This method enabled the simulation of a large, square truss plate comprising over 1000 members and 250 joints.

2.2 Qualitative Review of Simulation Results

In order to make intelligent use of large, detailed simulation models, it is necessary to have a method whereby simulation results may be reviewed both on a local scale and on a global scale. Time histories of motion or energy at individual points within the structure, and their associated Fourier spectra, provide an effective means for ascertaining the characteristics of local dynamic phenomena. However, many such histories or spectra must be correlated in order to obtain information about the influence of local phenomena on global dynamics. This latter process is tedious, error-prone, and often ineffective due to the incomplete scope of the correlations. To alleviate these deficiencies, computer-generated animation was employed. The advantage of animation is that it provides a complete picture of the action of all phenomena of interest, both local and global, in their true, time-varying relationships.

A 16mm. animated film was produced for this contract which shows the time-dependent vibration energy and displacement patterns throughout the simulated truss plate structure. The features shown in this animation indicate the fundamental results of this research; substantive descriptions of which follow.

2.3 Influence of Local Member Dynamics on Global Response

The influences of local member characteristics on global dynamics were investigated by varying the slenderness ratio of the truss members. The lowest-order effect of this variation is to change the frequency of the fundamental member bending mode relative to that of the fundamental member axial mode. However, when the member bending mode frequency approaches that of the fundamental free-free mode of the truss plate, significant interactions occur. In particular, the response spectrum is quantitatively changed, the apparent period of the fundamental global mode is shifted (this occurs even in cases where member axial stiffness is held constant), and the magnitude of the global mode response is altered. Typical results are summarized in Table 1, below, for geometrically identical truss-plates composed of members of slenderness ratio 250, 429, and 600. For reference, a global-mode frequency of 2.9 Hz. is predicted for the simulated truss plate composed of members with infinite bending rigidity. The "High f " component referenced in Table 1 is a traveling-wave mode associated with reflection of vibration energy at the free edges of the plate. It is associated with a frequency of 18 Hz. in the simulations.

Table 1.
Effects of Uniform Variation of
Member Slenderness Ratio

| Slenderness Ratio s | Fundamental Member Bending Frequency | Observed Global Mode Frequency | Maximum Vertical Deflection | Peak Relative Amplitude of High f Component |
|-----------------------------|--|--------------------------------------|-----------------------------------|---|
| 250 | 5.2 Hz. | 2.9 Hz. | .0035 | 57% |
| 429 | 2.9 Hz. | 4.8 Hz. | .0037 | 68% |
| 600 | 2.1 Hz. | 4.2 Hz. | .0039 | 38% |

Examination of the frequencies associated with strain energy density in individual truss members reveals that traveling waves in the structure share a considerable portion of the total vibration energy. This is easily seen in the time history of bending-extension energy ratio of a single truss core member presented in Figure 1. Note that the two peaks which appear off the scale in this figure have values of 8 and 13, respectively.

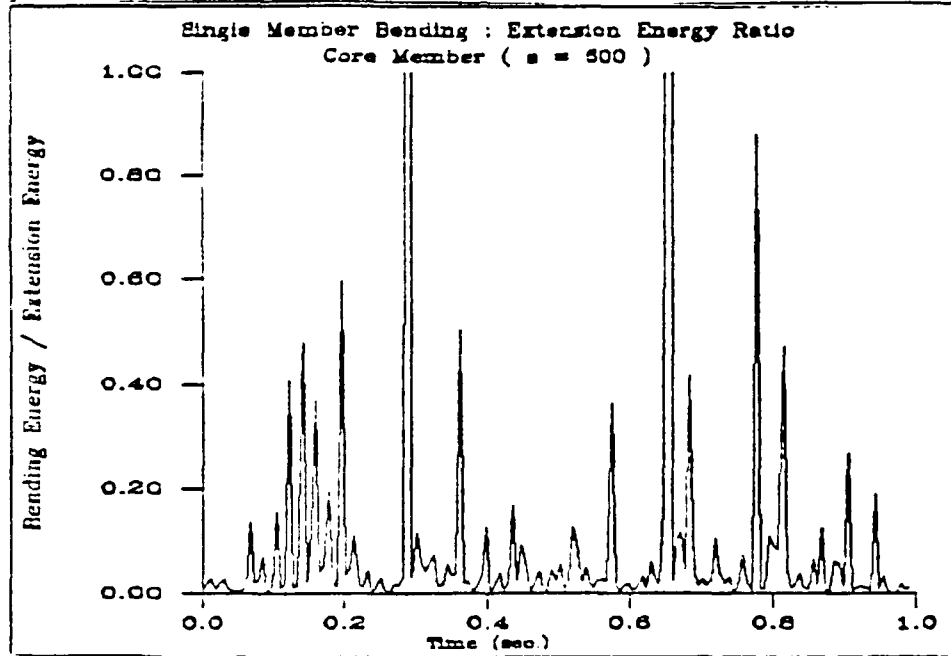


Figure 1. Single Core Member Energy Ratio

The implication of this phenomena is that significant modifications to vibration energy dispersion in the structure may be obtained by modification of individual member dynamic characteristics; i.e. by controlling the admittance of selected regions of the lattice-truss to certain dynamic disturbances.

2.4 Modification of Energy Dispersion Patterns

Based on the above-mentioned characteristics, observed locally within the lattice-truss plate, an effort has been made to demonstrate the effectiveness of dynamic tailoring of members to achieve better dispersion of vibration energy. This effort consisted of classifying members into one of three groups, based on their individual energy share in the plate free-free vibration mode which exhibited the frequency closest to that of the free-edge reflections of the traveling wave ($\sim 18 \text{ Hz}$). Members exhibiting the higher energy shares were stiffened.

The result of this tailoring was quite dramatic, as can be seen by the final sequences presented in the animated film. In the uniform truss case, high-energy waves are seen to propagate through the interior regions of the truss-plate throughout the response history. In the case of the tailored lattice, such high-energy waves are absent, and the vibration energy is nearly uniformly dispersed in the plate. Thus, dynamic tailoring of individual members has been shown to be a plausible means for improving energy dispersion characteristics of lattice-truss structures.

2.5 Observations

The present research has provided qualitative insight into the mechanisms and effects of vibration energy transfer among members of lattice-truss structures. The major contribution of this research is to have demonstrated the potential for modification of energy dispersion characteristics of a particular, realistic lattice platform by straightforward modification of local dynamic characteristics.

A quantitative method for predicting changes to energy dispersion characteristics was not developed. It was felt that such a method based upon the present studies would necessarily be inadequate for design of large lattice structures because several factors have not been included. In particular, the influences of local nonlinearities such as dynamic buckling of members, and contact (gap) and friction variables in a large number of structural joints have not been addressed. An initial effort to develop a numerically tractable algorithm for dynamic modeling of structures with large numbers of joints was made, and is described in "A Momentum and Energy Conserving Algorithm for Contact-Impact Problems" (LMSC-D060682).

3.0 Personnel

Two key personnel were involved with the execution of technical tasks under this contract. Dr. K. C. Park (Principal Investigator), Senior Staff Scientist, and Mr. Marc E. Regelbrugge, Research Engineer. No advanced degrees were sought or obtained in relation to the present research.

4.0 Interactions

The previous progress report entitled "Local-Global Interactions in the Transient Response of Lattice-Truss Plates" (LMSC-D878939) was presented at the 25th AIAA Structures, Structural Dynamics and Materials Conference, 14-16 May, 1984, and bears the paper designation AIAA-84-0945-CP.

In addition, Mr. Regelbrugge delivered a seminar to members of the Aeronautics and Astronautics Department at the Massachusetts Institute of Technology on the subject matter of this research on October 1, 1984. Prof. E. F. Crawley of M.I.T. was the sponsor of the seminar.

5.0 Discoveries, Inventions, and Patent Disclosures

None.

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